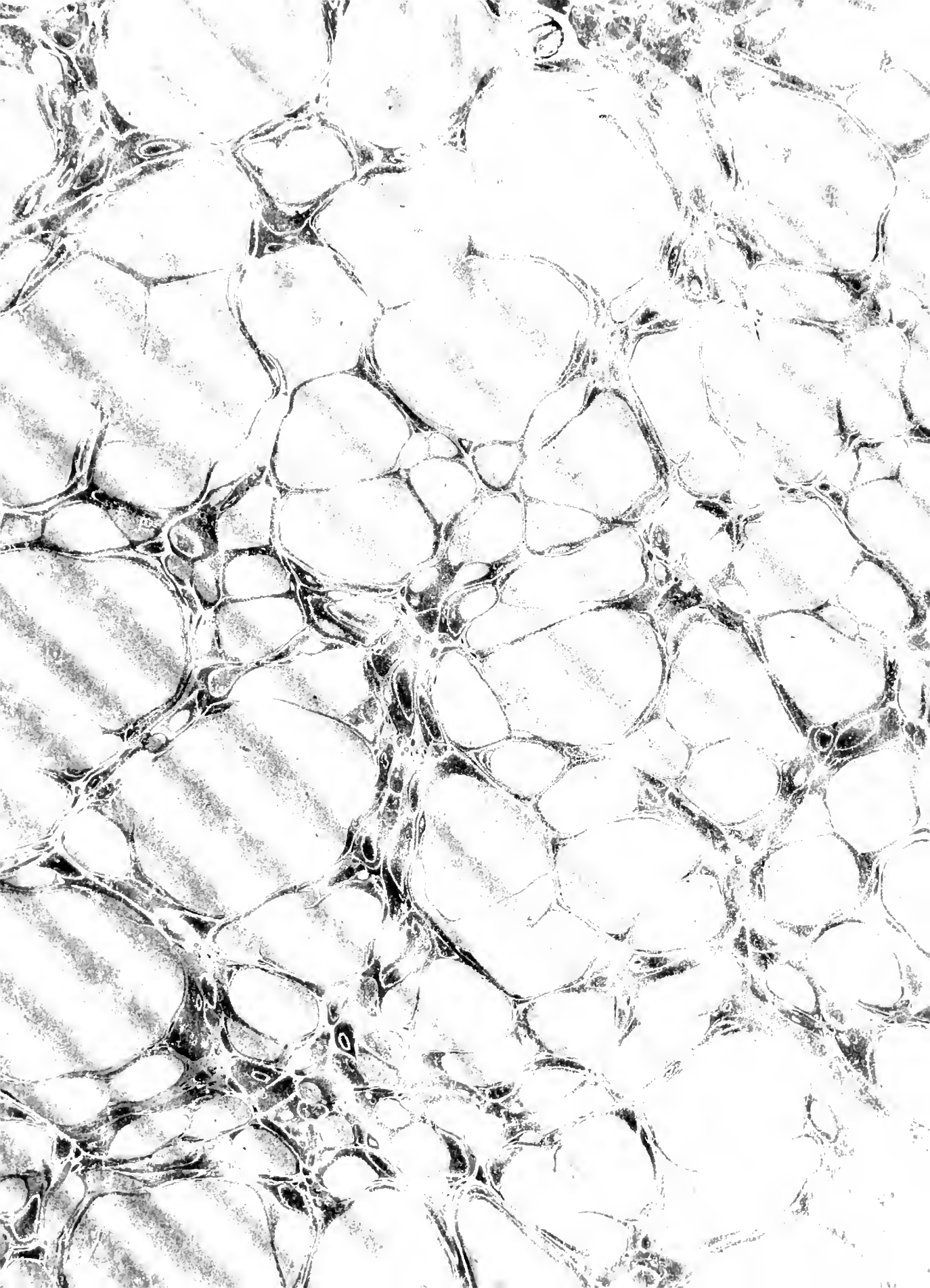

[illegible]

[illegible]

DISSERTATION

SUBMITTED TO THE BOARD OF UNIVERSITY STUDIES

OF THE JOHNS HOPKINS UNIVERSITY

IN CANDIDACY FOR THE REQUIREMENTS FOR THE

DEGREE OF DOCTOR OF PHILOSOPHY.

BY

MILTON ANNE ADLER.

BALTIMORE

1900.

C O N T E N T S

[illegible]

[illegible]

[illegible]

Introduction.

[illegible] importance of accurate determinations of the wavelengths of [illegible] course fully recognized, and [illegible] has recently been [illegible]. The [illegible] work has resulted in [illegible] spectroscopic [illegible]. Very great improvement of instruments has been brought about, and [illegible] has been [illegible] differences between the values found and the accepted ones.

As the [illegible] are obviously [illegible] would accepted, the necessity of repeating [illegible] formerly used, will [illegible] appear. This fact, however, [illegible] still [illegible] the accessibility [illegible] 11.5 [illegible] 70000 lines per [illegible] demand [illegible].

Apparatus.

Grating spectroscope. - [illegible] mounting, [illegible] Rowland mounting [illegible] described by Professor Ames*. The scale [illegible] used [illegible] a grating ruled with [illegible] produced [illegible] lines [illegible] angstroms [illegible] spectral [illegible], [illegible] of [illegible] spectrum [illegible]. The [illegible] satisfactory [illegible] the [illegible] [illegible].

---

* [illegible]

the upper pole positive. The arc-stem was rigidly fixed in position at a distance of 1.5 cm. from the slit and in line with the slit and the grating. The light was focussed on the slit by a movable quartz lens supported by the stem which was rigidly fixed in line with the slit and the grating.

The iron arc for comparison was a 3-ampere arc such as has been described by Pfund.* The terminals were placed in the same stand used for the arc of the other substance.

By means of a shutter with a horizontal slot of the same width as the thickness of the shutter and on a horizontal axis, the spectrum of the substance was taken in the centre of the plate and the comparison spectrum on the two ends.

As mechanical shifts were found to cast plates several methods of correctly determining the true relative positions of the lines of the two spectra were used. By taking plates of which the lower half was positive pole of the substance and the negative pole of iron, the true relative positions of the lines could be determined. When the impurities common to the two arcs were sufficiently strong, the mechanical shift was also quite accurate. A further, and more satisfactory, method was to load the positive

---

* Astrophys. J., 27, 190.

[illegible] ...ple from the source, in a fill..., and our dust, i... ...ixed in the ratio 1:1:... In all cases all reasonable... used. The last solution was necessary to use the iron arc for comparison, besides obtaining spectrical effects. To test whether the iron lines obtained by using the mixture suffered any displacement because of the presence of the other substances, exposures were made giving the arc of the mixture on the centre of the plate and the standard iron arc on either side. An examination of the ends of the lines showed that no displacement had occurred.

Spark Spectra.

Apparatus and Method.- The spark used was produced by a 110-volt alternating current of 25 amperes with a frequency of 60 cycles per sec. By means of a transformer the voltage was "stepped up" to 2000, this in turn "stepped up" to about 20,000 by another transformer. This potential was sufficient to produce a spark of about 6 cm. length. The spark terminals were of conical shaped metal, which was resharpened for each exposure in order to keep the spark steady.

In parallel with the secondary circuit were placed seven condensers consisting of copper foil and glass separated by moisture-free transformer oil and having a capacity of .02 micro-farad.

The spark used was [illegible], and its image on [illegible] was about 1 mm. The capacity that gave the best sparking results was so small that no self-induction was introduced and .001 micro farad, which answers reasonably constant throughout the work on the wave-lengths of the spark lines.

The comparison arc consisted of looped carbon poles as described above. The terminals of both arc and spark were fixed in exactly similar sliding clamp-rods, having but one degree of freedom, which were inserted in the same sockets of the fixed arc-stand. Hence on the plate insured the same positions of arc and spark relative to the slit. Moreover, as the focussing lens remained in position after one exposure, any difference in the positions of the two sources was at once detected by the displacement of the image on the slit. Although care was taken to have the positions the same, tests, which will be discussed later, proved that great caution was necessary.

To avoid mechanical shifts as far as possible, the shutter of the camera box was detached and fastened to clamp-stands resting on the floor, and the plate-holder was secured. As in the case of the arc spectra the shift could be detected by comparing the lines in the two spectra due to impurities. But to avoid any possibility of error due to a mechanical shift the methods of half-exposure was used, i.e. the plate was exposed half-time to the spark, full time to the arc, and then half-time again to the spark.

The exposures were made in the second order spectrum, for which 1 mm. = 10 A.U. is approximately equal to 1 mm. on the plate. Seed's Gilt Edge No. 2, Cramer's Isochromatic, and Wratten & Wainwright's Panchromatic plates were used. As the Gilt Edge plates are not sensitive to the $H\alpha$ line, no yellow screen is necessary. The plates were developed with pyro.

Measurement.

In calculating the wavelengths, the standard iron arc lines as determined by Hasselberg and Fabry* were used. The measurements were made on a dividing-engine constructed by Rowland especially for this work and fully described by Humphreys.** After reducing the scale readings to Angstrom units by means of a curve fairly different from linearity, corrections were made from a calibration curve for each plate which was drawn from the standard wavelengths as a scissaes and the differences between these wavelengths and the readings of the same lines as ordinates. The corrections for each line could then be read off the curve.

As a check on the work, two plates were taken so as to overlap.

In estimating the intensities, the iron arc line $\lambda 4045.8$ was used as the standard, and its intensity is marked 10, the same as was adopted by Kayser.

---

* Compt. Rend. No. 21, 1905; Journ. de Physique VII, 1908.
** Astro. Phys. Journ. 1, 180, 1895.

c

Symbols.

$\underline{M}$ indicates that the line to fill-in-the-blank or is doubtful; $\underline{n}$ that the [illegible] clouds on the less refracted side; $\underline{n'}$ that it is [illegible] more refracted side; and $\underline{r}$ that it is also reversed.

Algorithm.

Wa ele t s	I te sities Arc	Syra.	Varels t s	I t. alit s Arc	Chri
3974.9x6	4	8	3075.190	0	
13.293	2	4	7x.e3x	0	
1000.xxx	7	7	x0,17x		
3.727	6	7	84.132		
1 .176	3	10r	6x.x2x	0	
89.713	4	10	89.394		
43,542	3	1	9x,127		
43,447	3	3	9x.176		
46.771	7	7	1101.811		
18,766	4	3	-.800		
5 .782	1	4	8.x7		
55,075	8	7	x.225		
9.761	5	7	8.800		
60,452	1	1	7.453		
89.454	1	2	9.576		
96,197	2	7	10.374		
96.357	1	1	11.278		
96.513	5	4	12.080		
72. 29	5	4	12.478		
72,999	6	7	14.092		
7 .971	15		17.x54		

Hafnium.

Double Tube	Intensities.		Double Arc	Intensities.	
	Arc	Spark		Arc	Spark
2117.660			3141.090		
1[illegible].[illegible]			11.760		
19.745			24.557		
27.595			44.519		
28.071			70.513		
[illegible].764			72.721		
34.640			79.254		
39.009			83.970		
50.790			86.454		
55.915			90.868		
62.513			92.058		
63.473			95.707		
69.730			97.501		
74.736			99.908		
77.254			3201.568		
48.030			2.524		
52.299			3.420		
53.501			4.015		
4.164			4.886		
55.654			5.045		
57.590			6.542		

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	...arc	...ar...		...	...
[illegible],1[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	5		[illegible]	1	1
[illegible], 14	[illegible]	1	[illegible]	1	1
[illegible],[illegible]	4	4	[illegible]	[illegible]	1
[illegible],527	[illegible]	[illegible]	71,[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	1	[illegible]	[illegible]	1
[illegible]	1	[illegible]	[illegible]		[illegible]
[illegible],[illegible]2	[illegible]	1	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	1	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	1	[illegible]	[illegible]	1
[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	1	1
[illegible]	1	1	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1
[illegible]	1	1	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
,[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	37,96[illegible]	[illegible]	1
,[illegible]	[illegible]	[illegible]	[illegible]	2	
,[illegible]		[illegible]	1,[illegible]	[illegible]	1

[illegible]	[illegible]	[illegible]	4215.[illegible]
[illegible]	[illegible]	[illegible]	24,[illegible]
[illegible]	3	[illegible]	[illegible].41
[illegible]		[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	4	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	4	10	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]
[illegible]	[illegible]		[illegible]
[illegible]	3	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]			[illegible]
[illegible]			[illegible]
[illegible]			[illegible]
[illegible]			[illegible]
[illegible]	[illegible]		[illegible]
[illegible]	[illegible]		[illegible]
[illegible]			[illegible]

Manganese.

Wavelengths	Intensities Arc	Spark	Wavelengths	Intensities. Arc	Spark
2812.845	3	3	2892.406	2	4
13.488	3	1	92.672	2	1
13.997	2	1	97.810	2	
14.935	2	3	98.006	2	
15.618	2	1	2900.565	1	4
17.198	2	1	2.212	2	
17.986	3	1	7.736	3	1
18.710	3		8.004	1	1
			8.866	1	1
18.844	1		14.618	2	2
21.571	2	1	20.480	1	1
22.561	3	1	23.728	1	1
28.806	2	1	24.450	1	1
30.807	3	2	25.597	6	2
36.528	2	1	28.699	3	1
58.670	2		30.153	2	
72.554	2	1	33.068	7	6
74.980	1	4	34.034	3	1
82.516	1	1	35.663	2	1
86.688	1	4	38.314	7	6
89.550	2	6	40.350	2	1
89.692	1	3			

Manganese.

Wavelengths	Intensities Arc	Spark	Wavelengths	Intensities. Arc	Spark.
2940.512	6	1	3045.589	3	2
41.047	3	1	45.615	2	1
41.694	1	1	47.040	3	2
41.755	1	1	54.369	6	2
44.410	1	1	62.131	5	2
49.224	3	2	65.034	5	2
53.031	1	1	70.306	5	2
63.615	2	1	73.149	5	2
78.582	2	1	79.042	5	2
3002.492	1	1	81.331	4	2
7.657	2	1	87.052	4	2
11.171	2	1	3110.066	5	2
11.378	2	1	13.037	1	1
15.462	3	1	13.808	2	1
22.754	3	1	15.473	5	2
40.601	3	2	20.342	2	1
41.251	2	1	22.866	1	1
43.146	2	2	25.023	1	1
43.348	3	2	26.058	1	1
43.773	5	1	32.296	2	1
44.592	6	5	32.503	2	1

Manganese.

Wavelengths	Intensities Arc	Spark	Wavelengths	Intensities. Arc	Spark.
3136.960	2	1	3236.762	6	6
42.674	3	1	37.572	6	2
48.188	5	2	40.373	4	2
58.751	1	1	40.604	4	2
59.340	2	1	43.778	5	4
61.053	5	2	46.508	4	4
77.053	1	1	51.117	4	3
78.415	6	3	52.937	5	4
89.957	1	1	56.140	5	5
90.927	2	1	58.410	4	4
3201.121	2	1	60.212	4	3
2.539	2	1	64.692	4	4
3.736	2	1	67.794	3	3
6.894	3	1	68.703	3	2
12.862	5	3	70.347	3	2
16.928	3	2	73.010	3	2
20.226	2	1	78.544	3	2
24.745	4	2	80.640	1	1
26.015	3	2	80.744	5	1
28.071	7	5	90.979	2	1
30.700	5	4	95.836	2	1

Manganese.

Wavelengths	Intensities Arc	Spark	Wavelengths	Intensities. Arc	Spark.
3296.027	2	1	3354.652	1	
96.872	3	2	56.226	2	2
98.330	3	3	3407.984	1	1
3300.956	2		19.601	1	1
3.277	3	2	35.570	3	2
4.898	2	2	38.978	3	3
7.008	3	1	41.998	5	10 n
8.765	3	1	50.624	2	2
11.906	3	2	60.350	5 n	10 n
13.199	3	2	74.064	4	8
13.814	3	2	74.136	4	8
14.419	2	1	82.924	4	10 n
14.898	3	2	88.678	4	10 n
16.328	3	2	95.045	5	8
16.452	1	1	97.526	3	8
17.304	4	2	3524.548		8
20.693	4	2	31.839	4	8
30.666	4	1	32.002	5	8
43.729	3	2	32.128	5	8
45.354	3	1	47.790	5	10
51.665	2	1	48.025	4	8

Manganese.

Wavelengths	Intensities		Wavelengths	Intensities.	
	Arc	Spark		Arc	Spark.
3548.187	4	8	3669.839	1	1
52.737	2	1	70.518	3	1
69.485	5	8	76.950	3	2
69.796	8	8	80.147	1	1
70.081	4	6	82.091	2	2
74.085	1		84.866	1	1
77.865	7	8	91.815	1	
79.656	2	1	93.668	4	4
80.120	1		96.588	4	3
83.692	2	1	3700.302	1	1
86.536	5	5	1.733	3	2
89.980	1		6.074	4	4
95.109	5	4	18.926	4	3
3601.279	1	1	31.925	3	3
7.530	6	6	46.613	3	2
8.532	6	6	50.758	2	1
10.298	6	6	56.651	2	1
19.407	6	5	63.376	2	2
23.794	5	4	67.686	2	1
29.740	4	3	68.261	3	1
60.405	3	3	98.262	2	

Manganese.

Wavelengths	Intensities Arc	Spark	Wavelengths	Intensities. Arc	Spark.
3706.456	2	2	3853.487	3	3
3800.551	2	2	56.603	3	3
1.909	2	2	64.107	3	2
6.709	3	1	72.046	3	2
9.360	7	8	72.456	3	2
9.119	2	2	73.373	3	1
.591	5	4	89.448	3	3
10.687	2	2	96.347	2	2
16.739	2	3	98.362	3	3
23.510	4	5	3904.315	1	2
23.882	4	4	4.980	2	1
24.712	3	2	11.120	3	1
28.485	3	2	12.424	2	2
33.836	5	5	16.628	2	1
34.381	6	6	18.312	3	2
36.508	4	1	21.766	3	1
38.329	4	2	22.[illegible]	[illegible]	1
39.776	4	4	23.35[illegible]	[illegible]	2
41.711	4	5	24.010	3	3
43.979	3	4	31.470	4	3
52.403	3	2	[illegible].954	3	2

Manganese.

Wavelengths	Intensities Arc	Spark	Wavelengths	Intensities. Arc	Spark.
3939.654	3	2	4011.534	2	1
36.757	2	2	18.083	5	5
42.974	2	1	20.063	3	1
52.844	2	2	26.226	3	2
75.883	2	2	28.601	2	1
77.081	2	2	31.797	18 nA	7
80.154	1	1	35.057	15 n	5
80.883	1	1	34.477	15 n	5
82.170	1	1	35.724	5	5
86.572	2	2	37.856	3	1
87.903	1	1	41.343	12	6
84.177	2	1	45.208	4	3
85.739	3	2	46.734	11	5
87.097	3	2	49.012	2	2
87.489	3	2	49.445	2	1
88.677	1	1	51.125	1	1
91.602	1	1	52.403	2	2
92.486	2	1	55.205	2	2
4001.110	1	1	55.545	10	4
3.859	1	1	57.948	4	2
.030	2	1	58.127	5	4

Manganese.

Wavelengths	Intensities Arc	Spark.	Wavelengths	Intensities. Arc	Spark.
4003.343	4	2	4110.917	6	2
04.741	5	2	10.240	3	1
08.553	7	3	14.409	2	1
15.019	3	2	18.250	1	1
16.221	6	1	18.770	2	1
17.998	3	1	20.240	1	1
20.208	2	3	20.543	1	1
23.251	2	1	21.130	1	1
29.204	7	1	31.510	1	1
31.170	7	1	31.628	2	1
35.922	3	1	35.033	4	2
43.120	1	1	37.275	2	
49.938	3	1	40.060	3	2
51.349	2	1	41.330	3	1
54.040	1		44.794	3	2
55.245	2	1	46.450	1	1
4402.070	2	1	47.003	3	1
03.470	1	1	48.594	4	3
04.310	3	1	49.998	3	2
05.370	3	1	4501.740	1	1
07.220	2	1	01.770	2	2

Manganese.

Wavelengths	Intensities Arc	Spark	Wavelengths	Intensities. Arc	Spark.
4260.613	3	1	4321.351	3	4
31.725	1	4	47.410	1	1
35.703		1	52.564	0	1
3 .723	6	3	60.535	2	1
37.613	5	3	68.015	4	3
41.289	2	1	71.012	5	3
45.990	5	3	75.320	5	3
52.182	2	1	85.820	5	3
53.095	5	3	5 .051	5	2
54.094	5	2	5 .735	3	4
4300.203	2	1	98.216	5	4
12.54	4	1	00.389	4	2
23.402	1	1	01.090	6	4
24.039	3	2	02.037	7	5
31.701	3	2	04.260	1	1
38.639	3	1	10.139	2	1
4405.084	2	1	18.900	1	4
12.875	3	2	22.700	3	2
14.880	6	4	30.071	5	3
19.774	3	2	37.149	3	2
36.051	2	1	43.647	3	1

Manganese.

Wavelengths	Intensities Arc	Intensities Spark	Wavelengths	Intensities Arc	Intensities Spark
4498.898	1	5	1995.700	2	1
4502.218	6	5	06.901	2	1
3.813	3	2	39.840	2	1
23.407	2	1	44.312	3	1
42.451	3	1	54.613	1	1
44.427	2	1	54.805	1	1
48.589	3	1	62.052	1	
4605.378	5	3	4665.976	3	1
26.552	5	3	74.349	1	
31.694	4	1	85.777	2	1
4701.110	3	1	5004.910	3	1
3.708	7	4	10.330	2	1
27.476	7	4	29.818	1	1
39.004	6	3	30.648	1	1
54.046	10 nr	6	74.906	2	1
61.521	6	4	86.715	1	
62.375	8		5117.944	3	
65.659	6	4	49.855	1	
66.414	5	4	50.937	2	1
83.451	10 n	6	94.603	5	3
4823.521	10 n	6	97.038	2	

Manganese.

Wavelengths	Intensities Arc	Spark	Wavelengths	Intensities. Arc	Spark.
5255.330	6	3	5750.168	6	2
60.774	3	1	5916.837	5	2
98.033	2	1	48.951	4	2
5341.068	8	5	6013.480	10	10
77.623	7	4	16.631	10	10
88.526	6	4	21.794	10	10
94.679	7	3			
99.494	6	4			
5407.429	6	3			
13.690	4	2			
20.371	6	6			
32.553	4	2			
70.644	7	4			
81.401	6	2			
5505.874	3	5			
16.774	6	4			
37.753	4	3			
51.991	3	3			
73.016	1	2			
73.688	2	2			
5738.287	6	2			

Vanadium.

Wavelengths	Intensities Arc	Spark	Wavelengths	Intensities Arc	Spark.
3198.234	2		3210.674	5	
30.361	1		13.917	4	
33.336	1		21.503	3	
34.944	4		29.098	10	
36.587	3		3300.105	4	
41.500	2		1.227	2	
42.483	4		2.376	10	
45.354	4		4.139	3	
45.979	2		5.268	3	
47.275	2		5.575	1	
55.405	2		7.404	7	
62.568	2		8.351	4	
64.740	3		10.104	3	
68.136	3		10.433	2	
73.407	15		12.396	7	
83.984	15		14.731	4	
85.402	15		15.380	3	
87.700	7		17.119	4	
88.079	2		18.872	2	
88.503	5		26.109	3	
89.078	2		27.125	2	

Vanadium.

Wavelengths	Intensities Arc	Spark.
5227.418	3	
11.018	3	
20.047	3	
31.952	3	
33.191	3	
35.550	2	
38.800	2	
34.519	3	
36.580	3	
37.879	3	
39.045	3	
41.177	3	
41.980	3	
45.287	2	
49.374	3	
50.776	3	
51.659	3	
53.911	3	
54.758	1	
55.653	3	
56.542	3	

Wavelengths	Intensities Arc	Spark.
5201.060	3	
02.075	3	
03.739	7	
05.504	3	
10.0.0	3	
67.650	13	
71.129	12	
71.650	2	
73.025	3	
76.130	15	
77.946	3	
79.645	4	
82.533	3	
83.310	3	
84.304	3	
84.503	3	
91.050	3	
95.245	3	
96.736	3	
3.053	3	
5005.256	2	

Vanadium.

Wavelengths.	Intensities. Arc	Spark	Wavelengths	Intensities. Arc	Spark
3[illegible]0.134	4		3385.949	3	
10.054	3		87.350	2	
20.147	5		90.368	3	
21.55[illegible]	3		90.775	5	
21.692	5		96.528	2	
24.3[illegible]	3		97.385	5	
27.[illegible]96	2		97.845	5	
28.407	4		3400.401	5	
29.650	3		1.049	3	
35.573	2		2.572	5	
36.3[illegible]8			3.306	5	
65.355	5		4.970	4	
65.550	6		5.160	4	
66.697	5		6.651	4	
71.126	3				
74.046	2		8.020	3	
76.065	4		9.101	3	
77.395	4		14.203	3	
77.647	4		17.075	3	
80.758	4		18.354	4	
84.606	3		23.674	5	
			25.075	4	

Vanadium.

Wavelengths	Intensities		Wavelengths	Intensities	
	Arc	Spark		Arc	Spark
3442.017	3		3512.064	2	
42.330	3		17.289	5	
43.819	3		19.165	3	
54..00	3		20.022	4	
56.530	3		22.565	3	
57.157	3		24.714	4	
58.415	2		25.767	3	
61.643	3		28.205	2	
62.188	2		29.729	4	
65.031	3		30.763	3	
69.477	4		33.606	2	
73.165	4		38.743	5	
76.942	4		34.739	2	
77.056	3		36.336	3	
78.203	2		40.533	2	
79.837	2		42.057	2	
3500.825	2		43.495	4	
3.199	2		45.188	4	
4.425	5		45.343	4	
5.087	4		45.922	2	
6.847	3		51.506	2	

Vanadium

Wavelengths	Intensities		Wavelengths	Intensities	
	Arc	Spark		Arc	Spark
3553.203	4		3592.534	2	
55.147	2		93.552	3	
55.739	2		3600.040	2	
56.241	3		5.565	1	
58.000	3		16.740	1	
67.165	2		33.462	2	
80.570	3		39.045	1	
82.136	2		41.108	1	
83.353	2		43.681	1	
86.275	4		44.750	2	
88.939	3		45.828	1	
71.042	3		47.359	1	
71.057	3		48.513	1	
73.518	3		52.455	1	
74.776	2		56.725	2	
75.135	2		60.599	3	
77.877	2		65.151	2	
80.826	2		67.757	3	
83.702	2		71.210	3	
85.751	3		72.414	2	
92.014	3		75.411	3	

Vanadium.

Wavelengths	Intensities Arc	Spark	Wavelengths	Intensities Arc	Spark
3075.705	4		3715.467	3	
76.695	3		19.017	1	
80.111	3		23.004	1	
81.287	1		24.201	1	
83.123	4		27.350	2	
86.203	3		29.047	1	
86.703	1		32.756	2	
88.073	3		34.426	2	
90.277	3		37.999	1	
92.283	3		38.752	3	
94.127	1		41.513	2	
95.347	4		45.807	2	
98.866	3		47.136	1	
99.027	1		47.592	2	
99.434	1		50.875	2	
3702.569	7		51.783	2	
4.703	3		52.308	2	
5.044	3		53.258	2	
5.380	1		54.714	1	
5.045	1		56.043	1	
8.725	2		58.858	1	

Vanadium.

Wavelengths	Intensities Arc	Spark	Wavelengths	Intensities Arc	Spark.
3799.[illegible]	2		3799.900	4	
00.803	1		3803.474	5	
01.444	1		3.780	2	
03.143	2		3.914	2	
04.079	2		6.805	1	
70.541	1		7.507	2	
72.154	1		8.525	4	
74.111	1		9.809	3	
75.720	1		13.494	3	
76.160	1		15.533	3	
78.680	4		17.854	1	
79.050	1		18.246	4	
81.409	2		19.978	4	
82.053	1		21.490	3	
84.671	1		22.014	2	
87.053	2		22.902	3	
90.326	3		23.229	3	
90.484	2		23.985	2	
93.619	2		24.196	2	
94.[illegible]	1		25.372	1	
95.473	1		27.827	1	

Vanadium.

Wavelengths	Intensities Arc	Spark	Wavelengths	Intensities Arc	Spark
3831.041	2		3855.367	4	
32.433	2		56.639	7	
35.815	2		56.870	3	
35.183	2		58.691	2	
36.065	2		59.928	3	
36.524	3		60.637	2	
37.630	1		62.237	2	
37.858	2		62.497	1	
38.958	2		63.319	1	
39.308	1		63.877	1	
40.148	1		64.557	4	
40.436	3		67.642	3	
40.751	1		71.091	2	
41.301	2		72.747	1	
43.001	2		75.557	5	
43.496	1		76.096	4	
44.446	2		85.785	1	
44.896	2		86.590	2	
45.018	2		90.136	5	
45.451	2		91.85.	3	
52.408	2		94.049	2	

Vanadium.

Wavelengths	Intensities Arc	Spark	Wavelengths	Intensities. Arc	Spark.
3896.159	2		3.27.932	3	
97.081	2		30.020	4	
98.281	2		31.347	3	
99.139	1		34.026	3	
3.00.180	2		35.143	2	
1.244	2		36.288	2	
2.253	5		38.216	2	
3.200	2		39.33[illegible]	2	
4.215	2		42.00[illegible]	[illegible]	
5.746	3		45.066	3	
8.317	1				
10.791	2				
12.202	3				
12.883	2				
14.329	2				
16.415	1				
20.497	2				
21.906	3				
22.429	4				
24.659	4				
25.246	4				

II. Effect of Capacity and Self-Induction on the Appearance of the Spark Lines.

In view of the work of Exner and Haschek[1], Hascheck[2], Hurst[3], Kayser and Runge[4], Kayser[5], Hasselberg[6], Cooper[7] and others on spark spectra, tests were made for the possible effect on the variability of the spark lines in consequence of varying the capacity and self-induction of the secondary circuit.

Apparatus and Methods.—The apparatus used was the same as that already described, with the addition of self-induction in series in the spark circuit. This self-induction was produced by coils of No. 10 copper wire, each 1 meter long and having 10, 20, and 100 turns respectively. The first and second were 6 cm. in diameter and the third 15 cm. The second was mounted within the third and the whole was so arranged that the self-induction could be varied within the limits, .0000 - .0012 henry, without stopping the spark.

---

1. Sitz. der Kais-Akad. der Wiss. in Wien 1897
2. Astrophys. Journ. 14, 161, 1901
3. " " 17, 236, 1903.
4. " " 19, 251, 1904
5. Handbuch der Spectroscopie 2, [illegible], 508-510.
6. Astrophys. Journ. 23, 11[illegible], 1905
7. " " 1905.

same possible, temperature was kept in all of our work.

The [illegible] plates by the two-plate objective method [illegible] intensity ratios between the limits of .0005 - .5 [illegible] self-absorption ratios between the limits .0000 - .0012 [illegible]. Special attention was given to those lines in the region near λ3900 [illegible] lines especially investigated by Gatterer, Junkes and Salvador, successively with the various combinations of intensity and self-absorption, but also with variations of both without stopping the spark in changing the plate. [illegible] a longer [illegible] effect of the stray lines would be caused [illegible], which, however, was not observed. In order to detect [illegible] selection of half-time exposure was used.

General Effects.

The general effect of the increase of current from 10 amperes to 30 amperes was to [illegible] the intensities of all the lines of any one element. No reversals were found.

Self-absorption [illegible] the air lines, [illegible] the time of exposure, caused the enhanced lines to revert to the [illegible] arc lines, by the characteristics of the spark [illegible] time of exposure, [illegible] enhanced lines to become symmetrical and sensitive, [illegible] the blue end of the spectrum. The air lines show little self-reversal, as would be caused by the same effect in self-absorption as in vacuum.

Increase in capacity shortened the time of exposure, rounded the lines and made the enhanced lines asymmetrical and diffuse, generally towards the red end of the spectrum. Large capacity caused a few lines to reverse.

Shifted lines.

The titanium lines which, according to some observers, show large displacements are lines that are either enhanced or are broad in the arc spectrum, and this fact seems to be the cause of the disagreement among investigators as to whether a true shift occurs. Kayser points out the difficulties of determining a true shift in regard to broad and asymmetrical lines. A true shift should mean a shift of the center of gravity, rather than the shift of the maximum point of intensity; but as there is at present no way of accurately determining the true center of gravity, owing to the variations of the area of the lines due to the time of exposure and of development, the center of maximum intensity is assumed to be the center of gravity.

So far as the writer has been able to discover, all calculations of shifts have been based on the position of the maximum intensity, which was found to vary slightly under different conditions of capacity and self-induction. In the case of broad lines, even if the title

li[illegible]λ5875.7 and 3918.5, [illegible] a [illegible] term [illegible], a [illegible]

or two, λ5804.77 and λ3998.64, are broad and asymmetrical in the spectra. All are subject to asymmetrical broadening under circumstances of opacity and self-reversal. Accordingly, in the present work there arose the difficulty of determining not only the true center of gravity but also the position of maximum intensity of each line.

The conclusion drawn from the evidence furnished by this investigation is that no determinable shift between arc and spark lines, or between spark lines subjected to different circuit conditions has been found.

The thanks are due to Professor Ames, under whose supervision the work was conducted, to L. P. Jewell, for his advice and assistance, and to Dr. Anderson and Mr. Ifurd, for their suggestions.